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With the Compliments of the Author.

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NOTES ON THE DEPOSITION OF SCORODITE FROM ARSENICAL WATERS IN THE YELLOWSTONE NATIONAL PARK.

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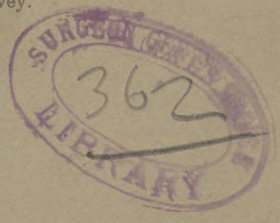

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ART. XX.—*Notes on the Deposition of Scorodite from Arsenical Waters in the Yellowstone National Park;* by ARNOLD HAGUE, of the U. S. Geological Survey.

SCORODITE, although a comparatively rare mineral, is usually found associated with arsenopyrite in several widely separated parts of the world. It occurs in minute orthorhombic crystals in many well-known mining regions and is frequently observed coating crystals of quartz. Hermann mentions an amorphous scorodite from Nertschinsk, Siberia, with nearly the theoretical composition. Quite recently Professor A. H. Chester* has reported its occurrence in the Horn Silver Mine, Utah, where it is observed in thin crystalline crusts and amorphous layers. Crystals of artificially prepared scorodite have been produced by Verneuil and Bourgeois† by submitting metallic iron to the action of arsenic acid in sealed tubes at high temperatures. So far as I know, however, its occurrence as a deposition from thermal mineral springs has never before been noticed.

Scorodite is found in a number of localities in the Yellowstone Park as an incrustation deposited from the waters of several hot springs and geysers. The best occurrence, although the locality is one difficult of access, is at the Joseph's Coat Springs on Broad Creek, east of the Grand Cañon. This group of springs is situated along both sides of the stream bed between rhyolite ridges which rise abruptly for two or three hundred feet. Solfataric action has completely decomposed the rhyolite into smooth, rounded slopes of soft earthy material unsurpassed in beauty of color by any other locality in the Park; orange, yellow, vermilion and white are interblended in a most striking manner. A hundred narrow vents deposit crystals of yellow sulphur far too delicate for transportation. Added to this coloring are the deep greens, reds and yellows derived from the algeous growths lining the hot water channels running off from the numerous springs. Mineral and vegetable colors vie with each other in brilliancy.

On the west side, about 100 feet from the stream and 10 feet above the water, is situated a boiling pool which at the time of my visit, although not seen in action, I regarded as an active geyser. The following accurate description is taken from the note-book of Mr. Walter Weed who accompanied me to the locality: "The water is perfectly clear, deep blue in color, sulphurous in odor, and in constant agitation, bulging and boiling vigorously for about a foot above the level of the pool. The basin measures 10 by 12 feet and is edged and rimmed in by a curious yellow deposit with the hollows and

* This Journal, April, 1887.

† Comptes Rendus, vol. xc, 1880.

spaces filled with a deposit of a brilliant green color. The steam is strongly sulphurous and is emitted in large volumes. The overflow is inconsiderable and runs towards the creek in a shallow channel which, near the spring, is lined with the same green coating."

Like all other springs of the group this one issues through fissures in the altered rhyolite, which, around the spring, is everywhere coated with siliceous sinter or geyserite derived directly from the hot waters. Deposited upon the sinter and intermixed with it, occurs the green coating. It lines the basin for about a foot or wherever the spray from the agitated waters falls upon the sides. Analysis shows this mineral to be scorodite, a hydrous arsenate of iron. The layers vary from a mere coating up to an eighth of an inch in thickness. Frequently the cavities and druses in the sinter are filled with scorodite and occasionally it forms nodular masses from a quarter to a half an inch in diameter. Wherever observed it occurs as an amorphous deposit, and when pure, leek green in color. Nitric and sulphuric acids apparently have no action upon the mineral but it is readily attacked by hydrochloric acid.

An analysis made by Mr. J. Edward Whitfield in the chemical laboratory of the Geological Survey, after neglecting a trace of sulphuric acid and a small amount of silica from which it was impossible to free the mineral, shows a nearly pure scorodite, closely agreeing with the theoretical composition. The result of the analysis is as follows:

Fe_2O_3	34·94
As_2O_5	48·79
H_2O	16·27
Total	100·00

Other localities for scorodite are Chrome Springs, at the base of Crater Hills, and one or two places in the Norris Basin. At the Constant Geyser in Norris Basin the water is thrown out two or three times a minute to a height varying from 10 to 20 feet. Around the vents the sinter deposits are finely laminated and show incrustations with greenish tints. Upon breaking off a piece of the sinter and examining a cross-section, thin layers and irregular deposits of scorodite may be observed. The scorodite is already partially altered to limonite and the sinter and pure mineral are more or less discolored by the oxide of iron. It is difficult to obtain a sufficient amount for analysis free from admixture of geyserite and iron oxide. A specimen from the Constant Geyser carrying much silica, yielded Mr. Whitfield as follows:

SiO_2	49·83
Al_2O_3	4·74
Fe_2O_3	18·00
As_2O_5	17·37
H_2O	10·62
Total	100·56

The scorodite, as it is found deposited from these thermal waters, is evidently a very unstable mineral and unless under favorable conditions for its preservation slowly undergoes oxidation, leaving an ochreous material carrying varying amounts of arsenic acid. Alteration into limonite readily occurs and the latter on exposure slowly disintegrates and is mechanically carried away by the action of the running water. Although pure scorodite is only sparingly preserved at a few localities in geyser basins, its identity with the well determined species from Joseph's Coat Springs is clearly made out, as it is easily recognized by the characteristic green color in strong contrast with the white geyserite and the yellow and red oxides of iron.

It may be well to add here that the vegetable green derived from the algeous growths found in nearly all the thermal waters of the Park is not to be mistaken for the mineral green of scorodite. The former is abundant in all hot spring areas, while the latter, a comparatively rare mineral, is obtained only in small quantities after careful search.

During the progress of the work of the Geological Survey in the Yellowstone Park, I have had collected a large number of samples of the thermal waters from the most interesting geysers and hot springs. These have since been subjected to searching analyses by Dr. F. A. Gooch and Mr. J. Edward Whitfield in the chemical laboratory of the Survey and their results which are of great interest will be published at an early date.

Unfortunately no sample of the water from Joseph's Coat Spring was obtained, but a careful analysis was made of the water from the Constant Geyser. This water was collected September 13, 1885; temperature 198° Fahr., the boiling point at this altitude; reaction slightly acid; specific gravity 1·0011.

For the purpose of comparison there is added here the analysis of the water from Old Faithful geyser in the Upper Geyser Basin. Date of collection, September 1, 1884; reaction, alkaline; specific gravity, 1·00096.

The analyses yielded as follows:

	Constant Geyser.		Old Faithful Geyser.	
	Grams per kilogram of water.	Per cent of total material in solution.	Grams per kilogram of water.	Per cent of total material in solution.
Silica	0·4685	28·88	0·3828	27·52
Sulph. acid	0·0923	5·69	0·0152	1·09
Carbonic acid	0·0155	·95	0·0894	6·43
Boracic acid	0·0317	1·95	0·0148	1·07
Arsenious acid	0·0018	·11	0·0021	·15
Chlorine	0·5740	35·39	0·4391	31·57
Bromine	trace		0·0034	·25
Hydr. sulph.	none		0·0002	·01
Oxygen (basic)	0·0185	1·14	0·0419	3·02
Iron	trace		trace	
Aluminium	0·0048	·29	0·0009	·06
Calcium	0·0146	·90	0·0015	·11
Magnesium	0·0018	·11	0·0006	·04
Potassium	0·0745	4·60	0·0267	1·92
Sodium	0·3190	19·67	0·3666	26·36
Lithium	0·0030	·19	0·0056	·40
Ammonium	0·00127	·08	0·00001	
Hydr. (HCl)	0·0008	·05		
Manganese			trace	
Calcium			trace	
Rubidium			trace	
Total	1·62207	100·00	1·39081	100·00
Albuminoid ammonia,	none			0·00002

Thermal waters from the Upper, Lower and Norris Geyser Basins do not differ essentially in their ultimate mineral constituents but show considerable variation in the relative amounts of the salts present. All the waters from the geysers which have been subjected to chemical analysis carry arsenic, the quantity present, according to Gooch and Whitfield, varying from ·02 to ·25 per cent of the mineral matter in solution. That the arsenic of the scorodite is derived from the thermal waters is beyond question, and in my opinion, it is supplied to the waters by the action of superheated steam upon the rhyolite lavas which form the great mass of volcanic rocks of the Park plateau.

While arsenic has been determined in nearly all these waters in no instance has the presence of even a trace of deleterious metal been detected. Arsenical waters of sufficient strength and suitable for medicinal purposes are of rare occurrence. In the United States an undetermined trace of arsenic is reported in the Orkney, Rockbridge Alum, and Roanoke Red Sulphur Springs in Virginia,* and Dr. A. C. Peale informs me that so-

* Mineral Springs in the United States; Dr. A. C. Peale. Bull. 32, U. S. Geol. Surv., p. 64.

dium arseniate has been mentioned recently as occurring in a mineral water in Asche County, North Carolina.

Hygeia Spring, which supplies the bath houses at the hotel in the Lower Geyser Basin, is an alkaline siliceous water carrying ·3 of a grain of sodium arseniate to the gallon. In the amount of sodium arseniate held in solution the Yellowstone Park waters fall below the celebrated arsenical springs of La Bourboule in the volcanic region of the Auvergne, which within recent years have acquired a well deserved reputation for their alterative properties in skin diseases. While the Yellowstone Park waters are somewhat less rich in arsenic than those of La Bourboule they must greatly surpass the latter in their enormous overflow. The entire supply from the springs of La Bourboule amounts to 1500 gallons per minute. During the past season the cauldron of Excelsior Geyser in Midway Basin alone poured into the Firehole river, according to the most accurate measurements which could be made, no less than 4400 gallons of boiling water per minute. According to the analysis of the sample collected August 25, 1884, the water of this geyser contained .19 grains per gallon of sodium arseniate. As yet we know very little about the remedial properties of the Yellowstone waters. At no distant day experience may show that they are decidedly efficacious in external applications and under proper medical guidance may take high rank as arsenical waters for the cure of certain forms of nervous affections and cutaneous eruptions.